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# Characterization Of The Effects Of Armor Weight Cab And Door Structure Of Medium Tactical Vehicles



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

Eric O'Brien  
RDECOM - TARDEC  
TWVS ATO  
Ground Systems Survivability

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## Door Sag Study Background

Part of the Tactical Wheeled Vehicle Survivability Army Technology Objective (TWVS ATO) involves the integration of B-kit and C-kit armor onto the existing M1083 A1P2 Medium Tactical Vehicle (MTV). During the TWVS ATO program, it was noted that the additional weight of the armor kits caused a noticeable drop or sag in the vehicle doors, which prohibited the doors from closing.

In an attempt to better understand the effects of the weight on the MTV cab and door, Finite Element Analysis (FEA) was performed both by the vehicle supplier and TARDEC CASSI. There were discrepancies between the two results of the FEA modeling and neither predicted the actual door sag. Therefore, it was determined that more information was needed in order to better quantify the phenomenon and identify areas for cab reinforcement.

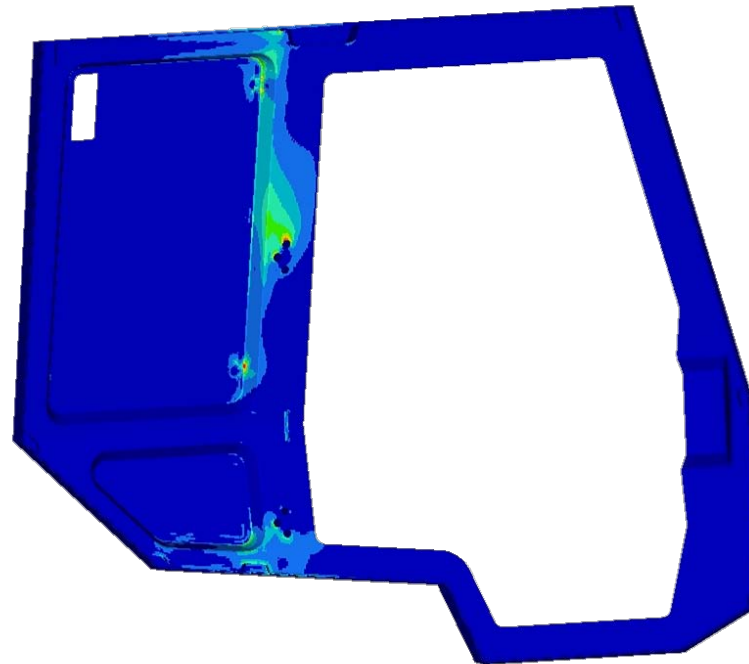
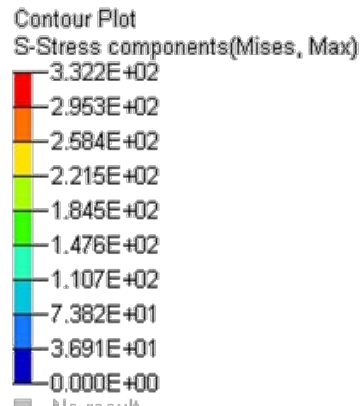
## Door Sag Study Objectives

- Quantify the sag that the door of the MTV experienced due to the added weight of the B-Kit and C-Kit
- Determine areas of the door or cab that contributed the most to the sag
- Recommend a path forward

## Study Methodology

- Spots on the cab were selected and labeled for strain and 3D measurement
- For door opening angles of 0, 10, 40, and 70 degrees, strain was measured on the cab using Rosette strain gauges and 3D measurements were taken using a probe arm measuring device
- A production metallic 6061 B-kit was placed on the door of cab and measurements were taken again for each door angle
- A surrogate C-kit was created by TARDEC/CGVDI for this study and was meant to closely approximate the actual C-kit weight and center of gravity. The surrogate C-kit was placed on the door of the cab and measurements were taken again.
- The cab was shaken on the Load Handling Simulator in TARDEC CASSI, then measurements were repeated with both the B-kit and C-kit still attached to the cab
- The B-kit and C-kit armor was taken off, and final measurements were taken
- Strain data was analyzed by TARDEC CASSI and 3D data was analyzed by CGVDI and TWVS ATO.

## FEA vs Measured Values - Strain



Maximum Stress = 332 MPa  
Safety Factor = 2.1

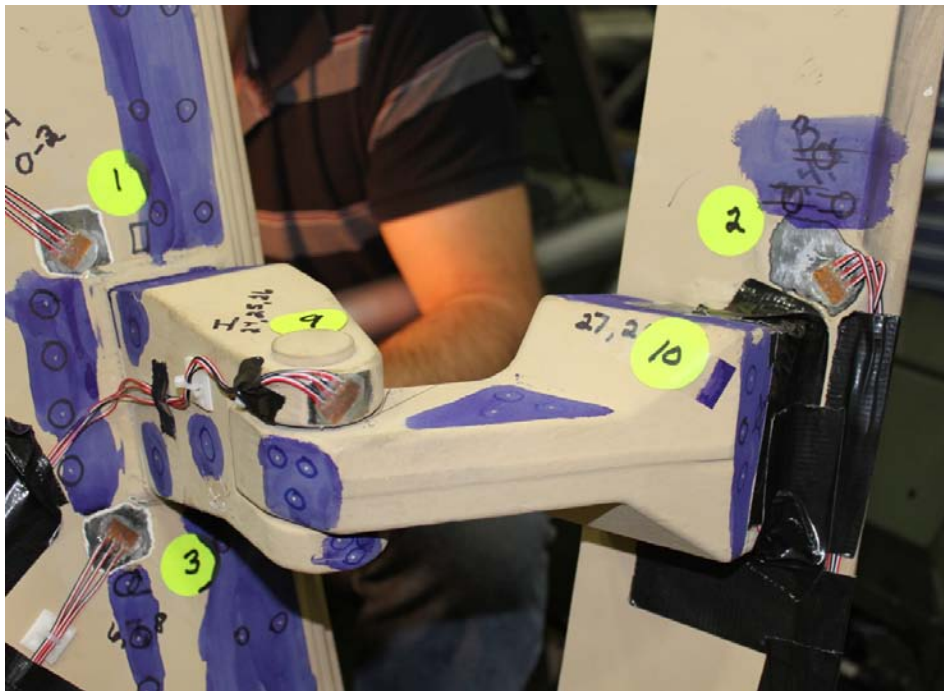
CASSI's FEA was similar to the vehicle supplier's

From the two models, locations for strain gauges were selected

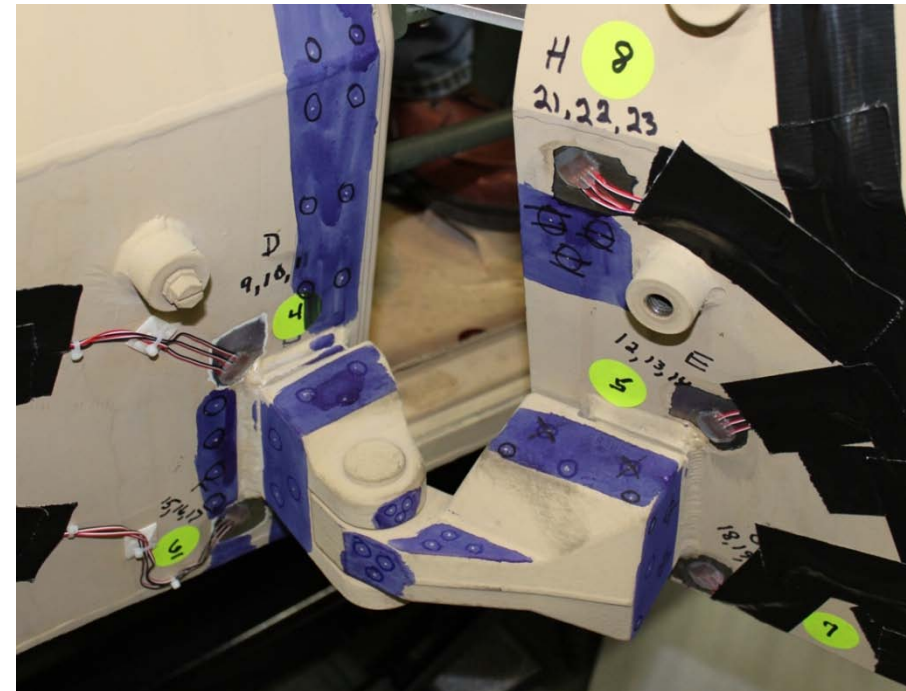


# Strain Gauge Placement

Top Hinge

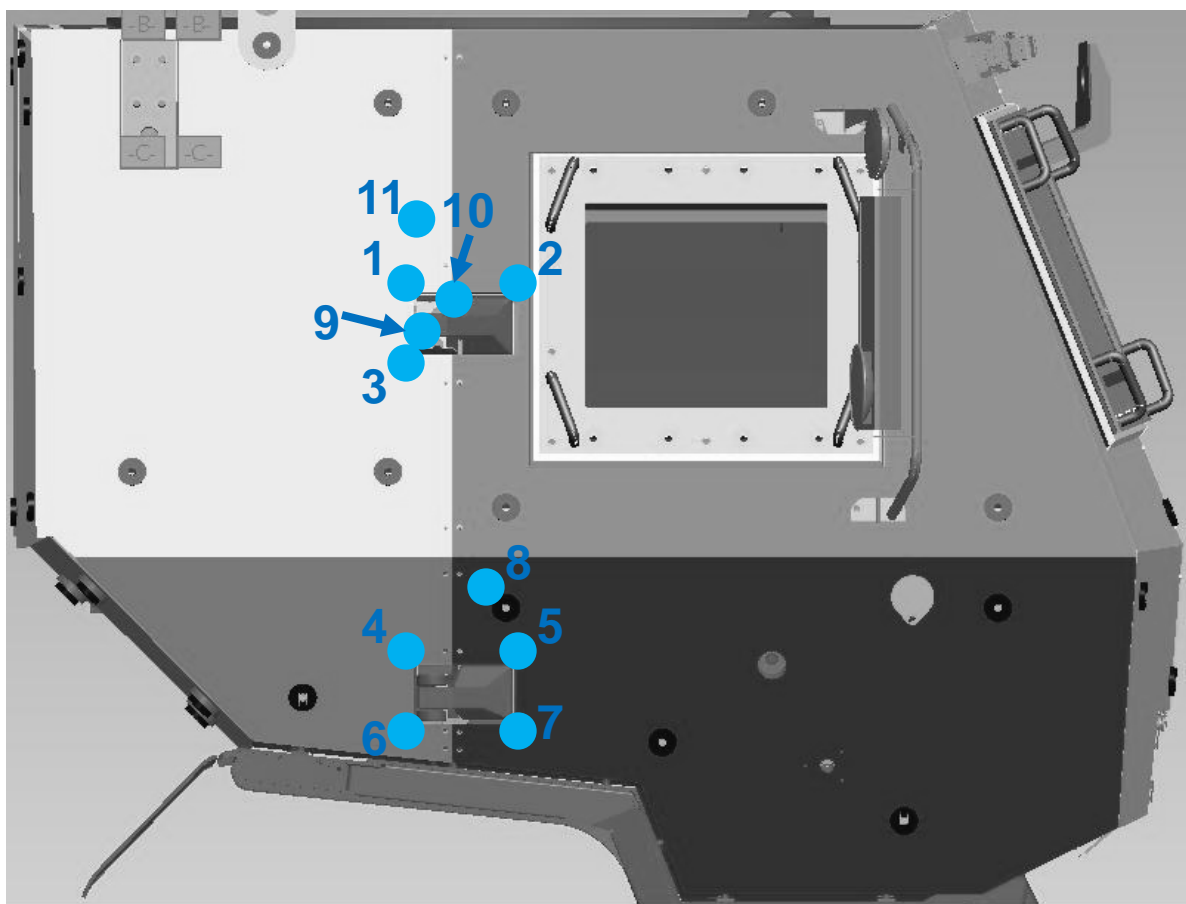


Bottom Hinge



Not Shown – Gauge #11 on the inside of the B-Pillar  
(roughly behind Gauge #1)

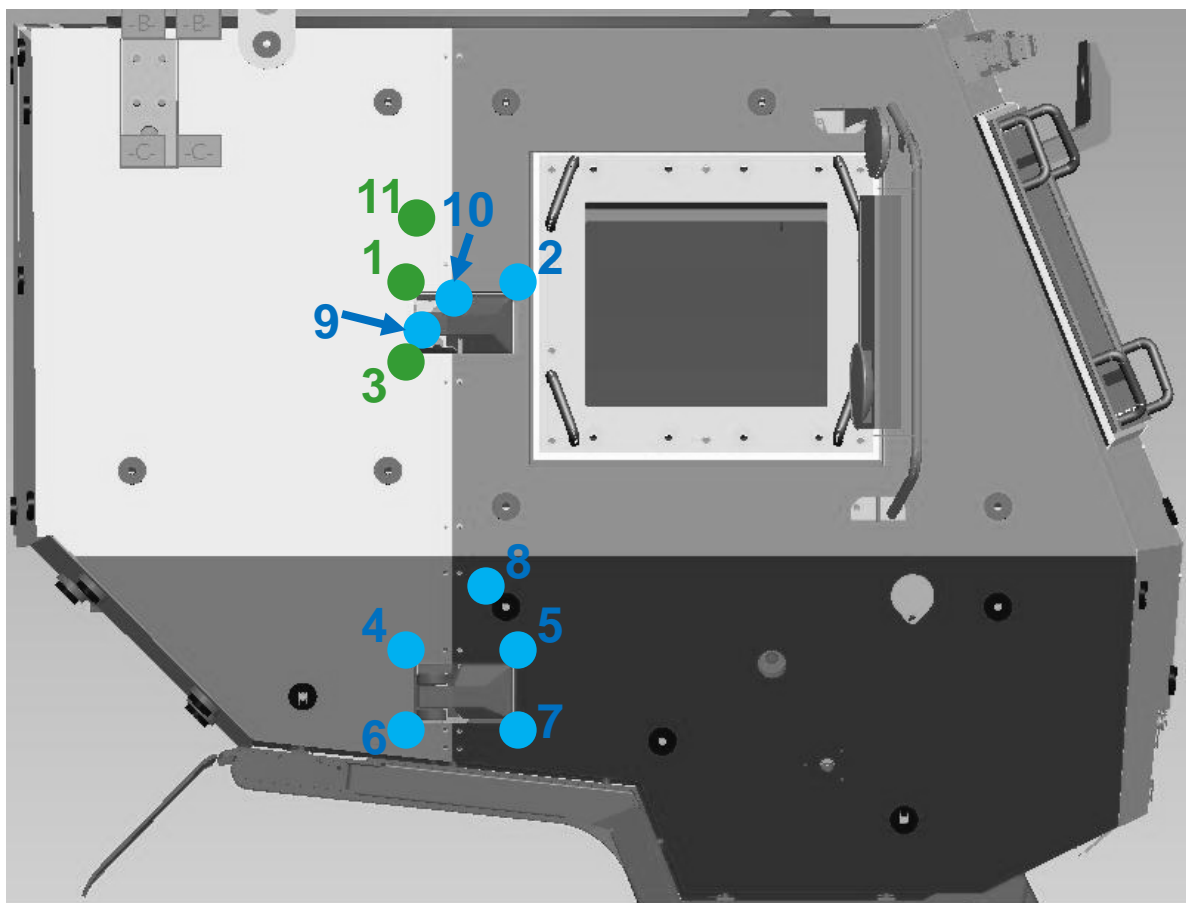
## Measured Peak Strain: A-Cab



- = 700–950  $\mu$ E
- = 450–700  $\mu$ E
- = 200–450  $\mu$ E
- = 0–200  $\mu$ E

1. Near top left corner of top hinge
2. Near top right corner of top hinge
3. Near bottom left corner of top hinge
4. Near top left corner of bottom hinge
5. Near top right corner of bottom hinge
6. Near bottom left corner of bottom hinge
7. Near bottom right corner of bottom hinge
8. Under belt line near hinge side of door
9. On the side of the top hinge
10. On the top of the top hinge
11. Inside of cab, mounted on B-pillar channel

## Measured Peak Strain: w/ B-kit

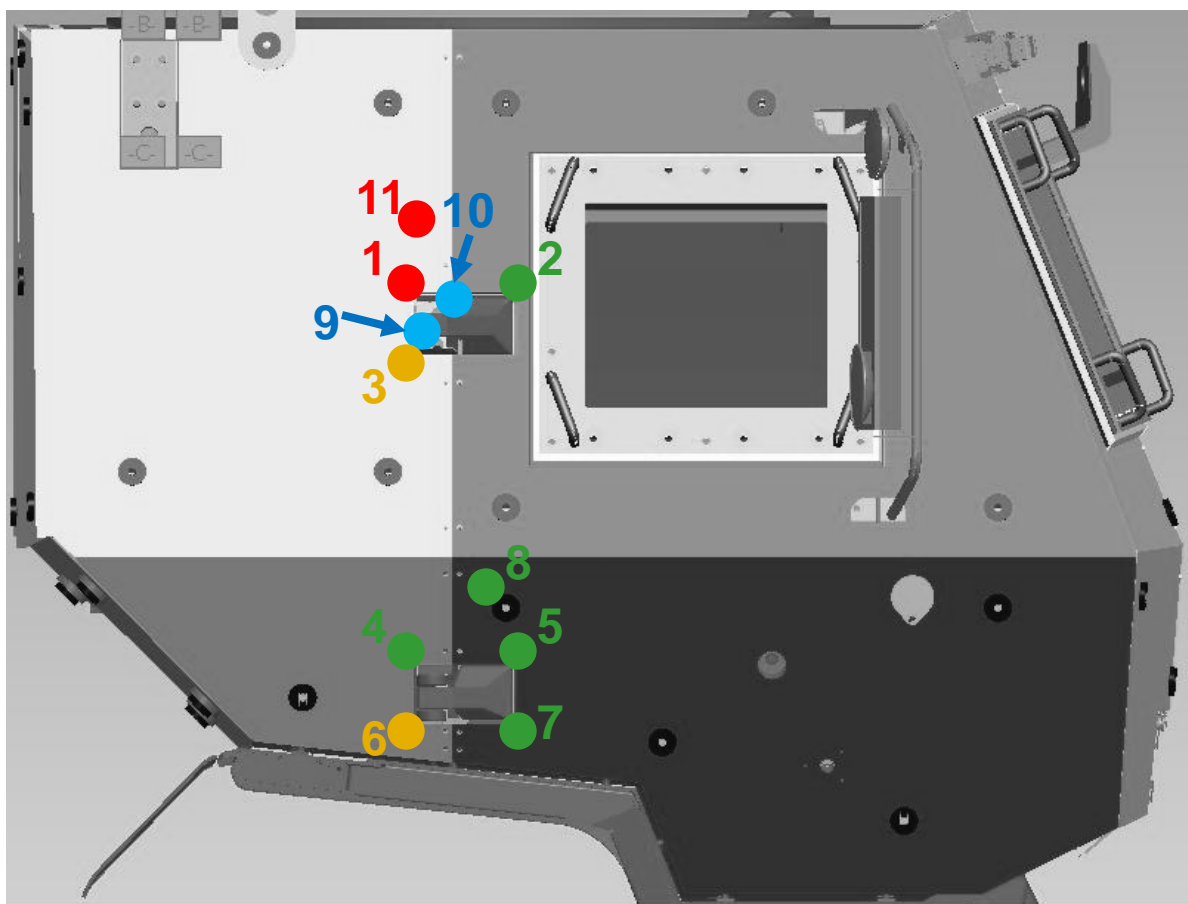


- = 700–950  $\mu$ E
- = 450–700  $\mu$ E
- = 200–450  $\mu$ E
- = 0–200  $\mu$ E

1. Near top left corner of top hinge
2. Near top right corner of top hinge
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5. Near top right corner of bottom hinge
6. Near bottom left corner of bottom hinge
7. Near bottom right corner of bottom hinge
8. Under belt line near hinge side of door
9. On the side of the top hinge
10. On the top of the top hinge
11. Inside of cab, mounted on B-pillar channel



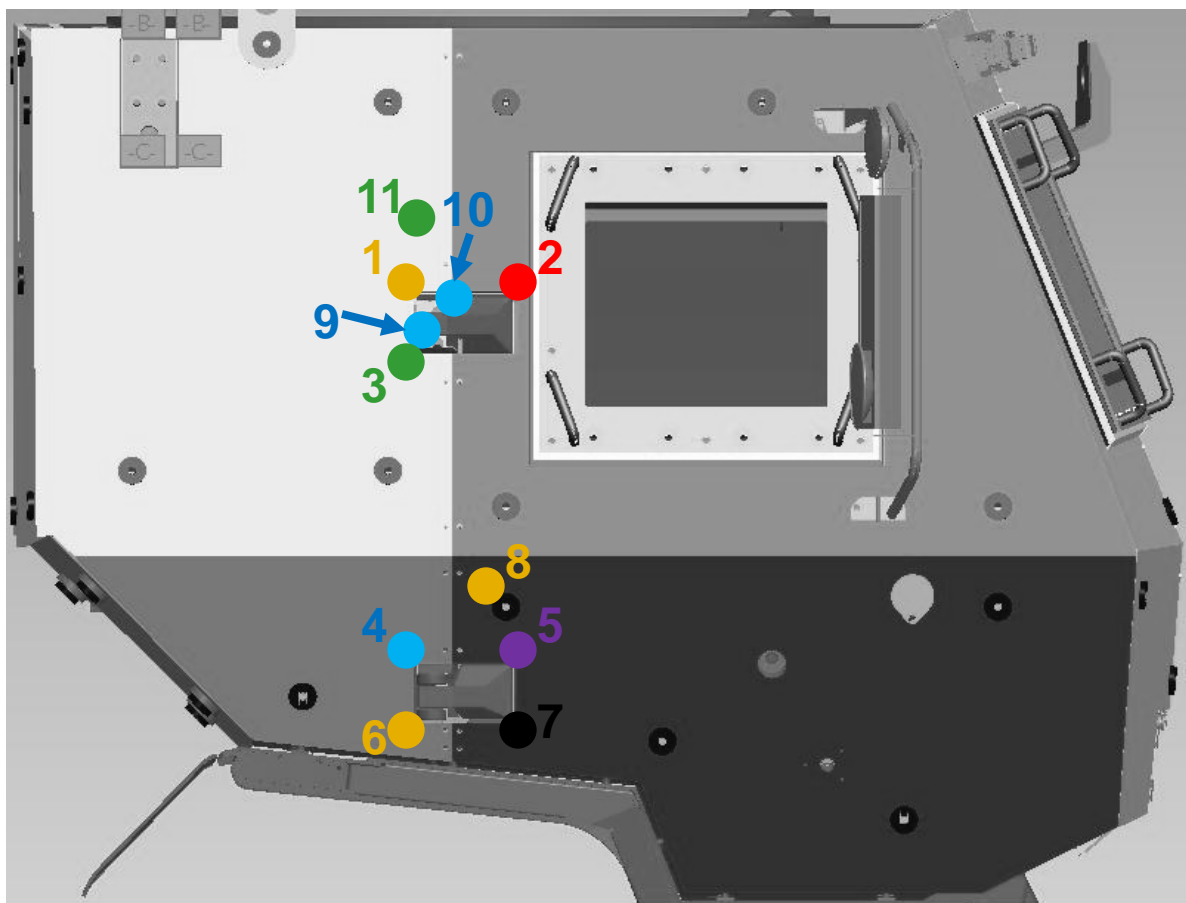
## Measured Peak Strain: w/ B-kit + C-kit



- = 700–950  $\mu$ E
- = 450–700  $\mu$ E
- = 200–450  $\mu$ E
- = 0–200  $\mu$ E

1. Near top left corner of top hinge
2. Near top right corner of top hinge
3. Near bottom left corner of top hinge
4. Near top left corner of bottom hinge
5. Near top right corner of bottom hinge
6. Near bottom left corner of bottom hinge
7. Near bottom right corner of bottom hinge
8. Under belt line near hinge side of door
9. On the side of the top hinge
10. On the top of the top hinge
11. Inside of cab, mounted on B-pillar channel

## Measured Peak Strain: Post Shaker w/ B-kit + C-kit



● = 950-3050  $\mu$ E

● = 700-950  $\mu$ E

● = 450-700  $\mu$ E

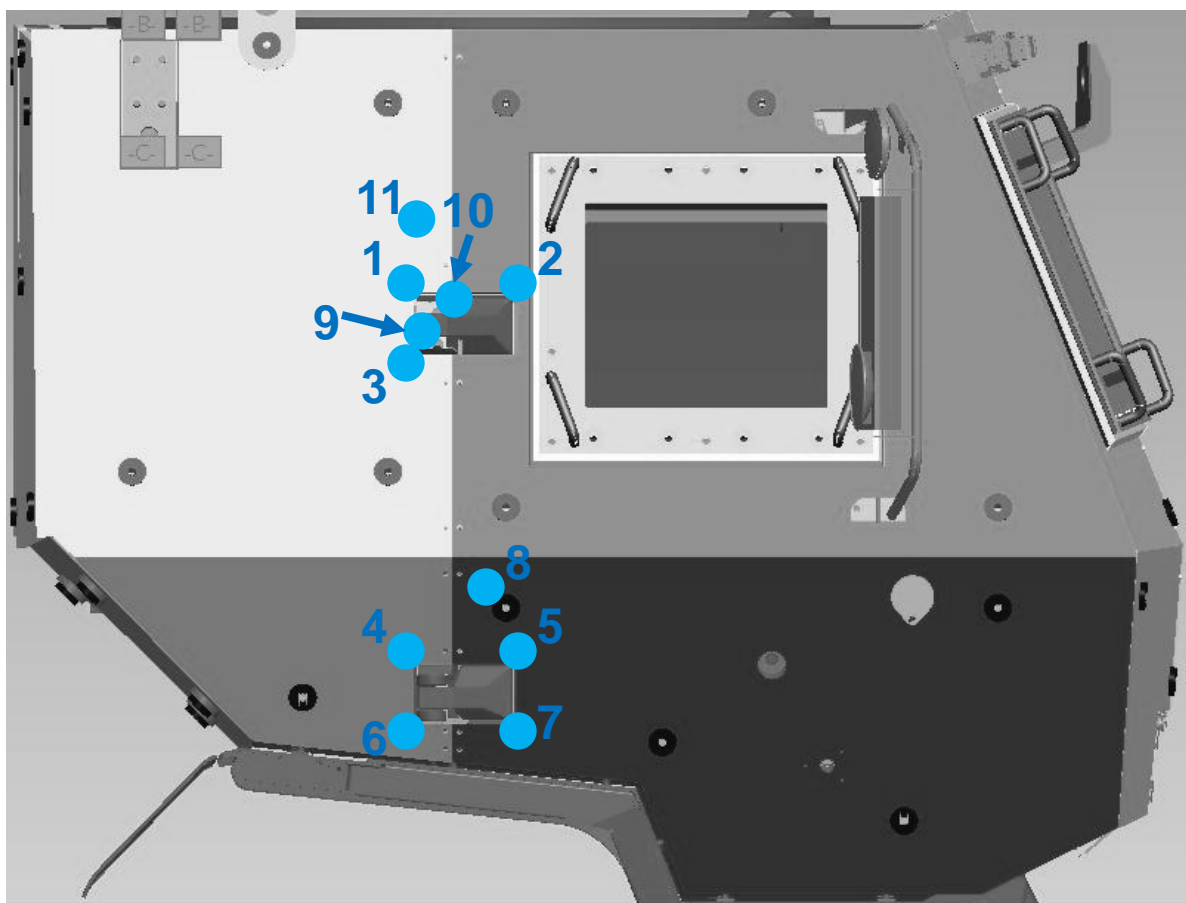
● = 200-450  $\mu$ E

● = 0-200  $\mu$ E

● = Damaged

1. Near top left corner of top hinge
2. Near top right corner of top hinge
3. Near bottom left corner of top hinge
4. Near top left corner of bottom hinge
5. Near top right corner of bottom hinge
6. Near bottom left corner of bottom hinge
7. Near bottom right corner of bottom hinge
8. Under belt line near hinge side of door
9. On the side of the top hinge
10. On the top of the top hinge
11. Inside of cab, mounted on B-pillar channel

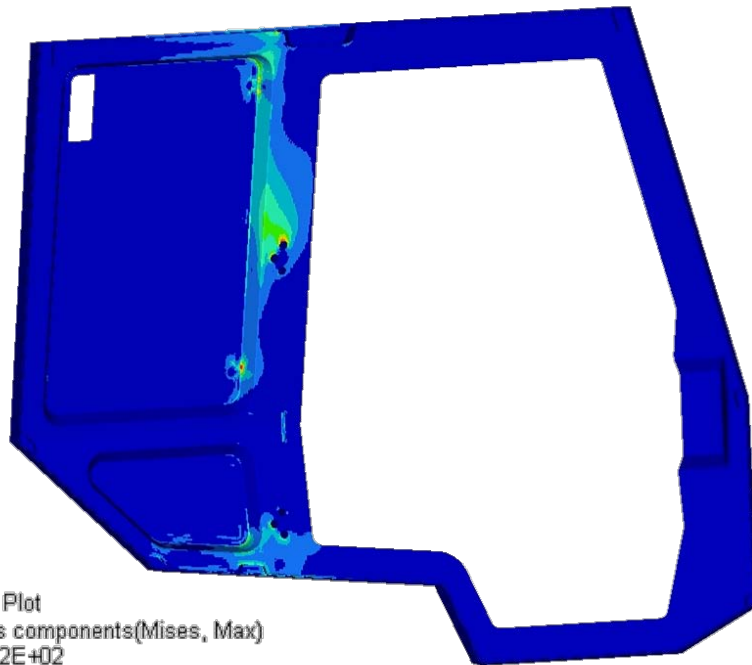
## Measured Peak Strain: Post Shaker A-Cab



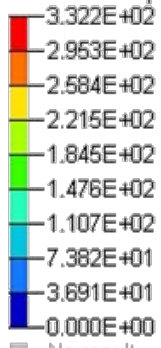
- = 700–950  $\mu\text{E}$
- = 450–700  $\mu\text{E}$
- = 200–450  $\mu\text{E}$
- = 0–200  $\mu\text{E}$

1. Near top left corner of top hinge
2. Near top right corner of top hinge
3. Near bottom left corner of top hinge
4. Near top left corner of bottom hinge
5. Near top right corner of bottom hinge
6. Near bottom left corner of bottom hinge
7. Near bottom right corner of bottom hinge
8. Under belt line near hinge side of door
9. On the side of the top hinge
10. On the top of the top hinge
11. Inside of cab, mounted on B-pillar channel

## FEA vs Measured Values – Strain with both B- and C-kits

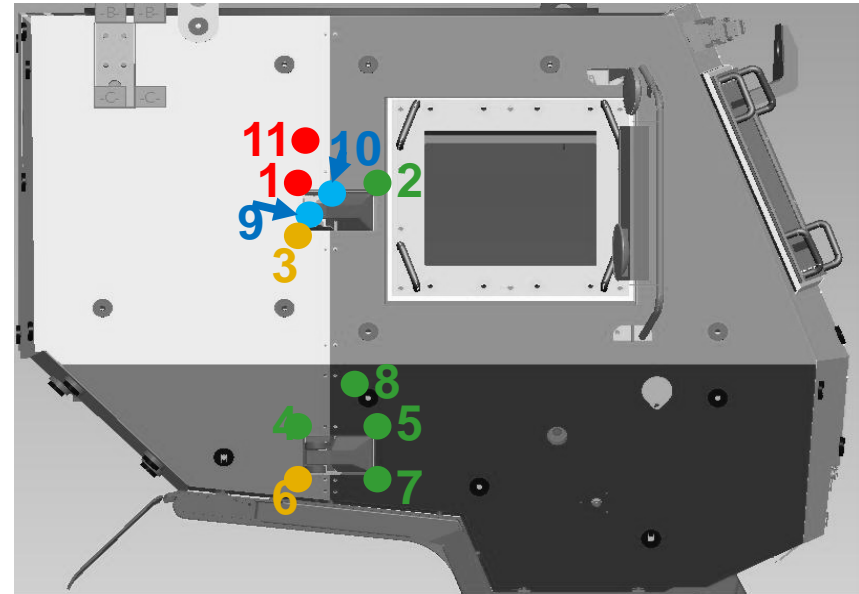


Contour Plot  
S-Stress components(Mises, Max)



Maximum Stress = 332 MPa

Safety Factor = 2.1



- = 700–950  $\mu$ E
- = 450–700  $\mu$ E
- = 200–450  $\mu$ E
- = 0–200  $\mu$ E



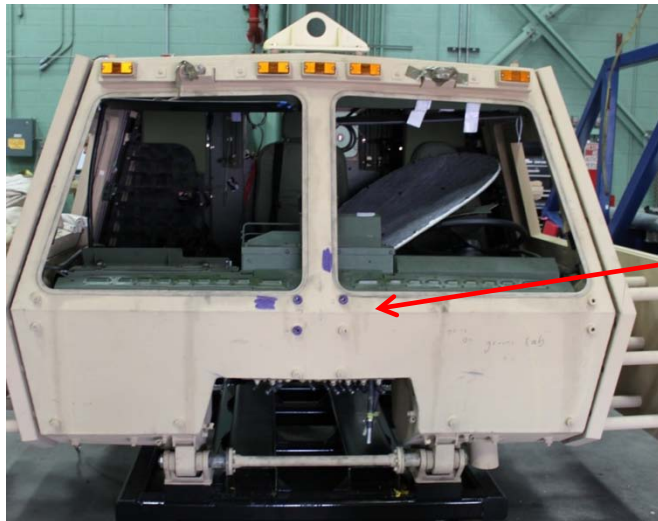
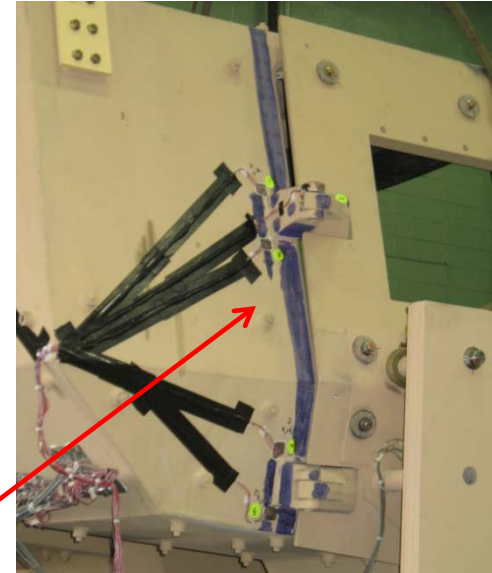
# Probe Arm Results



Probe Arm 3D  
Data Collection  
Points

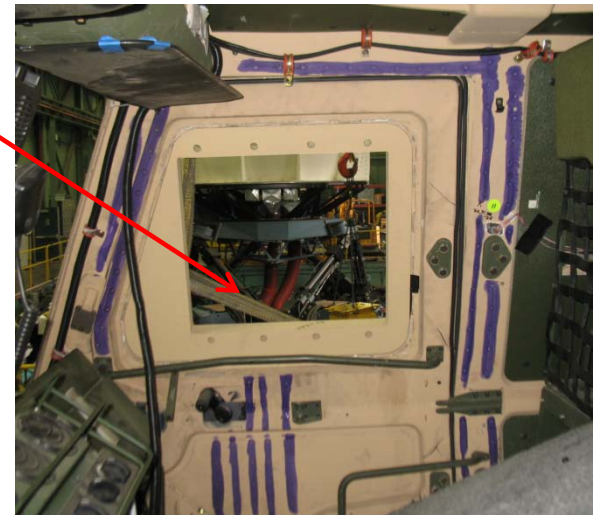
A-Pillar

B-Pillar And Hinges



Door And Inside Cab

Reference Points

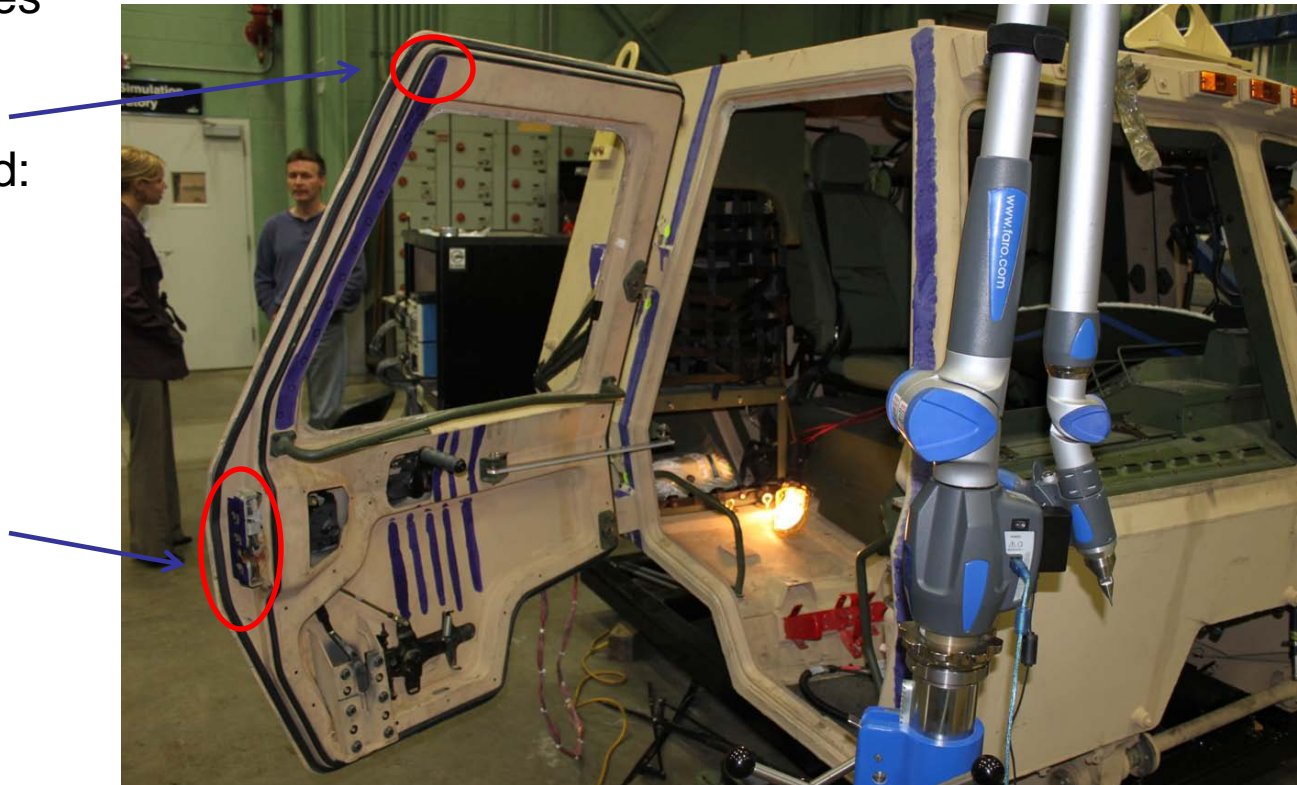




# Probe Arm Results

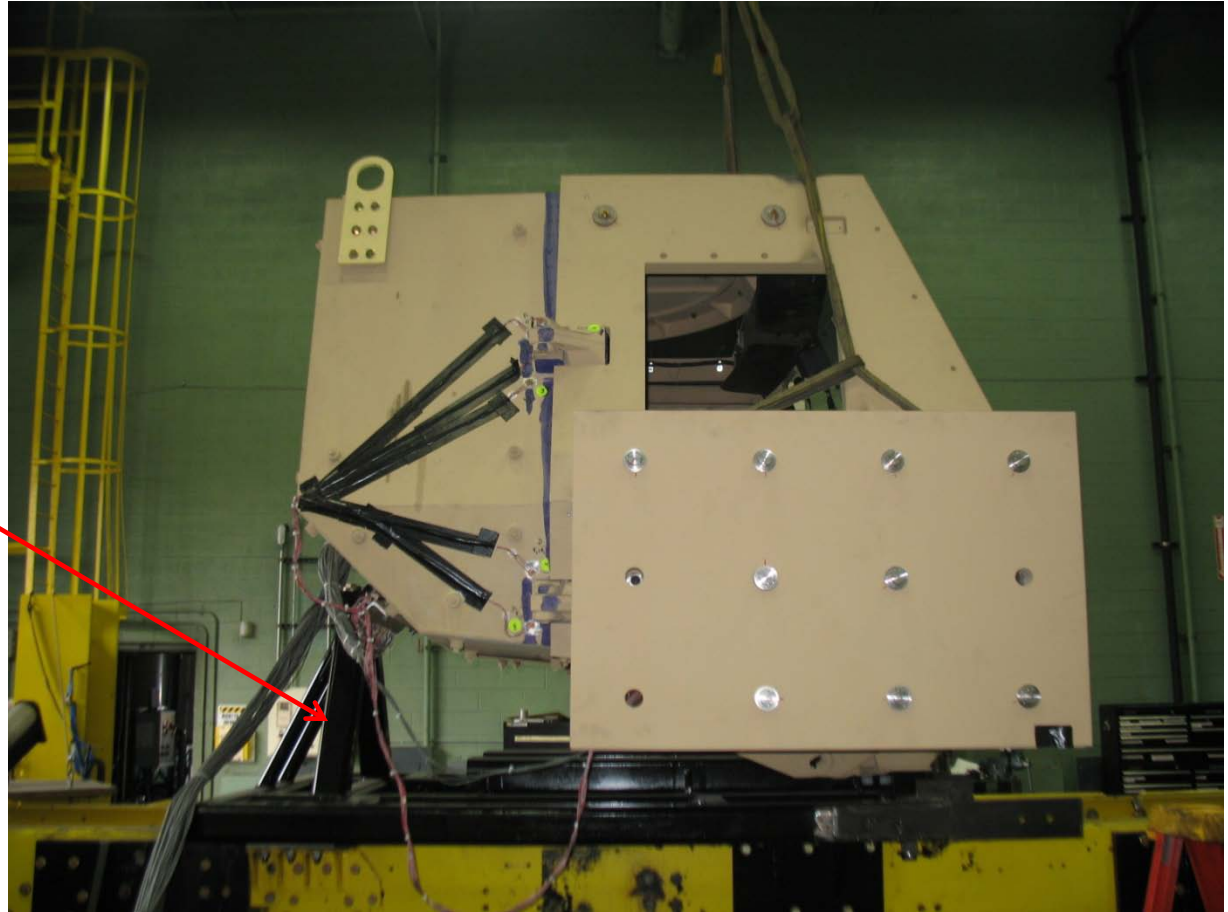
Quantify Sag At 10 Degrees Open

- Top Corner of Door Moved:
  - 0.27 in. Down
  - 0.23 in. Forward
  - 0.28 in. Outboard
- Latch Moved:
  - 0.32 in. Down



# Shaker Test

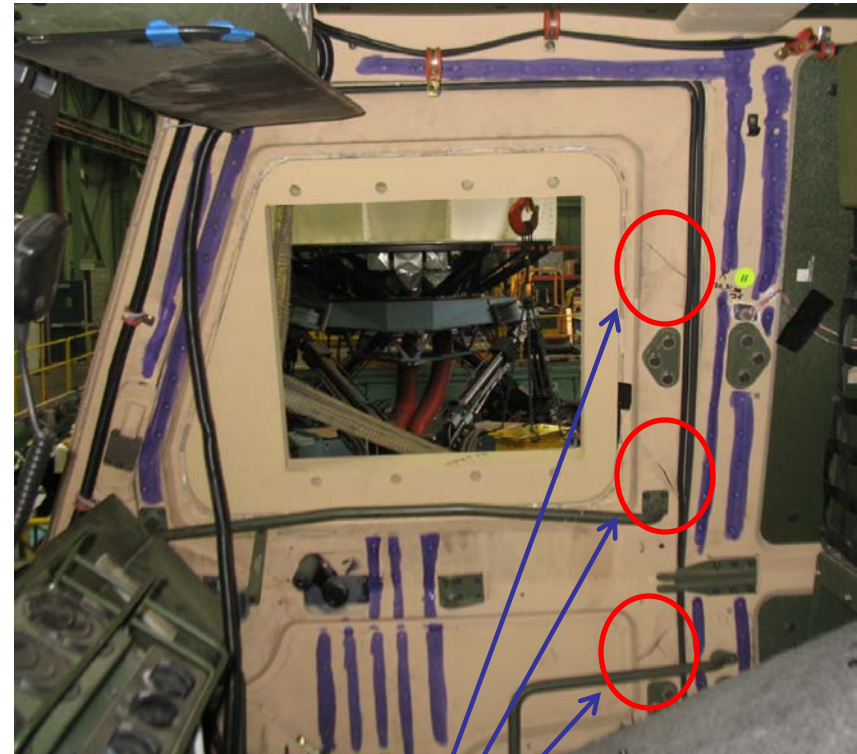
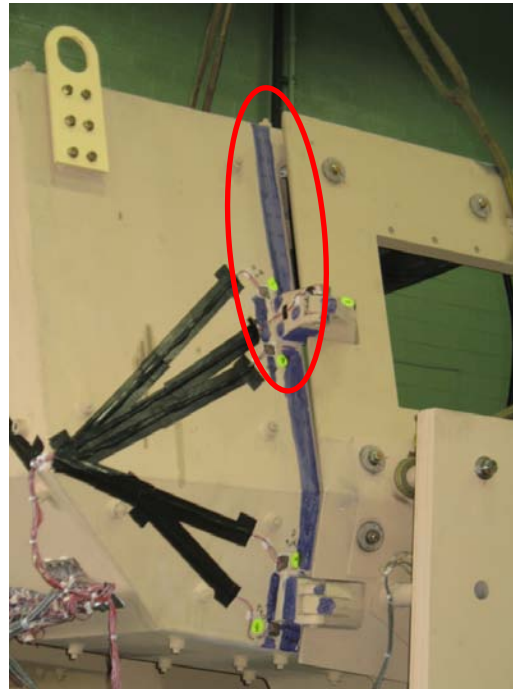
TARDEC Designed and Fabricated A Fixture To Mount An MTV Cab To The Load Handling Simulator For Shaker Tests.



# Shaker Results

## After Shaker Test (Aborted After 160 Miles)

Note: Doors were not fully latched, only one combat lock was engaged, and no door assist was included.



Cracks near hinge attachments



# Probe Arm Results

Contribution of each measured part to overall sag of the door

- A-Pillar – negligible
- B-Pillar – 20% (Deflected Outboard)
- Hinges – 60% (Top Hinge is Opening Up Slightly and Designed Clearances at Pivot Allow for Movement)
- Door Structure – 20% (Deflection at Hinge Attachments and Twisting)

# Path Forward

## Recommendations:

- Conduct Hinge Layout After All Testing
- Next Generation Hinge Needs To Be Larger With Tighter Tolerances At Pivot Point
- Strengthen B-Pillar and Door Near Hinge Attachment Points
- More Robust/Multiple Striker Strategy (Bank Vault)
- Improve FEA Analysis to Include Hinge and Door Components
- Conduct Similar Studies (FEA and Physical) on Other TWV's